THE EFFECTS OF VISUAL COMPLEXITY IN MOTION VISUALS ON CHILDREN'S LEARNING

BY

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Abstract of Dissertation Presented to the Graduate School
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The purpose of this study was to investigate whether differences in the level of visual complexity in motion visuals have an effect on cognitive learning of students in different grade levels. Specifically, this study examined the relationship between the amount of figure detail and background information and children's comprehension of information presented in an animated instructional video.

A 3 (levels of visual complexity) × 2 (grade levels) factorial, pretest-posttest design was used. The instructional content was a 14-minute video lesson concerning the motion of objects in the universe. The lesson was divided into three units: (a) motion and force, (b) gravity, and (c) the law of inertia. Three videotapes, which were converted from three versions of computer animation, represented three different levels of visual complexity in motion visuals for this study. They were outline drawings (OD), outline drawings with added figure detail (ODF), and outline drawings with added figure detail and background information (ODFB). Three fourth- and 3 eighth-grade classrooms were randomly assigned to one of the three video treatment groups. All subjects received the pretest, treatment, and posttest. Pretest and posttest consisted of 28 multiple-choice questions and were designed to test subject's comprehension of the instructional content.

The results of this study indicated that providing different levels of visual complexity in motion visuals had no significant impact on children's comprehension of the intended learning. The use of complex visuals contributed little to facilitate learner achievement. Also, no interaction between amount of visual complexity in motion visuals and grade level was found. These results imply that the comprehension level of children in grade 4 through grade 8 may not be affected by visual complexity in motion visuals. The issue of whether to add extra pictorial information in instructional materials should be an economic rather than an instructional consideration.

CHAPTER 1
INTRODUCTION

With the continually increasing impact of visual messages in our society, visual instruction has become one of the major methods of communicating information in school settings. A variety of visual materials, such as drawings, photographs, film, television, and computer software, is commonly used to complement regular classroom instruction at all levels of education (Dwyer, 1978, 1982-83). In light of such wide use of visuals in schools, it is important to determine the relative effectiveness of various pictorial stimuli on the attainment of specific learning tasks.

Prior research has demonstrated that pictures are a versatile instructional tool. They can substantially improve student achievement by (a) offering an alternative to learning through printed or spoken words, (b) providing a concrete framework for abstract concepts, and (c) increasing motivation as well as focusing attention on essential learning cues (Brody, 1984; Dale, 1946; Levin, 1983; Levin, Anglin, & Carney, 1987; Travers & Alvarado, 1970). However, studies of visual instruction also show that the inclusion of a picture in instruction does not automatically improve student achievement (Dwyer, 1978; Levie & Lentz, 1982;

Peeck, 1987). Different visuals containing different physical characteristics may affect learning differently.

How would learning outcomes be influenced by various levels of pictorial information contained in visuals for a learner to comprehend? Does added pictorial detail in visual displays accelerate learner's comprehension of the intended learning outcomes? If so, is this the case for all age groups, or does this effect vary developmentally, with children at different ages interpreting pictorial detail differently? Over the last half a century, these questions have generated an interesting and controversial debate in both educational and cognitive psychology. Much of this discussion has primarily centered around the role of visual stimulus complexity in influencing student performance in cognitive learning.

Despite the lack of a clear definition, visual complexity has been widely viewed as a determinant of attention and aesthetic preferences (Kreitler, Zigler, & Kreitler, 1974; Myatt & Carter, 1979; Travers & Alvarado, 1970; Vitz, 1966; Welch & Watt, 1982). Brody (1984) stated that "whether the level of visual complexity is defined in terms of the number of elements within a picture or the amount of detail represented, most people find complex pictures more interesting and will spend more time examining them" (p. 22). Research also has shown that most learners, regardless of their age levels, often prefer visuals that contain extensive detail even though it does not always facilitate learning (Borg & Schuller, 1979; Gorman, 1973). In light of this perspective, many teachers and instructional designers believe that the more complex and highly detailed visual stimuli would convey designated instruction more effectively than the less complex ones. For example, if illustrations in textbooks contain more background information or interior detail in figures, they usually are viewed by educators to be more attractive and therefore more effective for improving learning.

Furthermore, one trend in education today, arising from the progress in new technologies, such as videodisc and digital video, is that there is growing interest in the incorporation of increasingly detailed, complex visual images in instructional materials. Mills (1985) pointed out that the main assumption by many workers in digital imaging was that the most effective visual images can be achieved automatically by cramming more and more details (adding more pixels).

Overall, the justification for using complex visuals in instructional materials is primarily based on the theoretical works of Dale (1946), Morris (1946), Carpenter (1953), and Gibson (1954). Dwyer (1972, 1978) classified collectively these orientations as realism theories. Although they differ considerably in detail, the basic assumption underlying the realism theories is that learning will be more complete as the amount of visual detail in the learning situation increases. According to this orientation to designing instructional visual materials, realistic photographs are usually thought to be superior to simple line drawings in visual instruction.

On the other hand, a group of researchers argues that complex visuals may be interesting to view, but due to the limited capacity of human information processing, this type of visual is more difficult for the brain to process. Increases in the detail of visuals cannot add proportionally to the amount of learning achieved by the learner (Borg & Schuller, 1979; Dwyer, 1978; Hurt, 1988; Orderindi, 1975; Nelson, Metzler, & Reed, 1974; Travers & Alvarado, 1970). Micklos (1982) even indicated that excessive detail in a picture can act as a barrier to learning because such detail may become a type of visual "noise" to interfere with the transmission of the intended information. In general, this group of researchers suggests that a visual presentation should be simple enough so that only the information relevant to the learning task is provided.

In reviewing prior research on the effect of varied visual complexity on cognitive learning, two stimulus attributes in visual complexity have been implicated by researchers as playing a critical role in influencing learners to process the visual information (Dwyer, 1978; Fleming, 1987; Franken, 1977; Nelson, Metzler, & Reed, 1974;

Travers, 1969). These attributes are the amount of interior detail in figures and the presence or absence of added background information.

The effect of the amount of interior detail in figures on different types of educational objectives has been intensively examined by Dwyer and his associates (Dwyer, 1978, 1982-83). They developed eight visual sequences of the human heart with different levels of interior detail ranging from simple line drawings in black and white to realistic color photographs. In a series of studies, they found that visuals varying in amount of figure detail were differentially effective depending on the interaction with other variables, such as instructional objectives and learner grade level. The simple line drawing presentations, for instance, were more effective than realistic detailed illustrations for the drawing and identification tests rather than for the comprehension test. However, since only college and high school students were involved in the studies, more investigation needs to be conducted before Dwyer's results can be generalized to other age groups of subjects.

Research also indicates that the addition of background information within a visual, the second attribute of visual complexity, is an important factor influencing the storage and/or retrieval of visual information from memory (Antes & Metzger, 1980; Franken, 1977; Franken & Davis, 1975;

Palmer, 1975). Since figures are generally perceived relative to a ground, visual information that is too isolated can be misinterpreted or forgotten. Thus, Horton and Mills (1984) suggested that adding some contextual information is necessary to perception, learning, and understanding of a visual display.

However, one of the critical problems concerning the use of background information in visuals is whether this effect would be equally valuable for all age levels. It would be important to determine if younger children profit from the addition of background information the same as the older children. According to the research on selective attention, the answer seems to be uncertain. Many researchers have found that children's ability to selectively attend to some attributes of a visual is a skill that improves with age (Barrett & Shepp, 1988; Day, 1978; Pick, Christy, & Frankel, 1972). Older children are more able than younger children to filter out irrelevant information and to allocate their attention to a central task. In light of this viewpoint, the inclusion of background information in a visual is not an independent design variable; instead it should be taken into account with the age level of the intended learners.

The individual's response to visual complexity is based on his/her information-processing capacity and strategies, which are viewed by many researchers as varying with age (Gibson, 1969; Haith, 1971; Wohlwill, 1975). Thus, in selecting and designing a visual with the proper level of complexity, educators and instructional designers should not overlook the variable of learner's age level.

Several empirical studies have been conducted in the attempt to establish the relationship between the complexity of a picture and a child's ability to process it (Collins, 1970; Evertson & Wicker, 1974; Franken, 1977; Hagen, 1972; Haith, 1971; Hale & Taweel, 1974; Pezdek & Chen, 1982). In general, researchers agree that there are developmental increases in children's ability to process visual information. Young children before the age of 9 or 10 have greater difficulty in mentally manipulating pictures than do older children. For example, young children tend to center perceptually on selected aspects of a picture, while older students are better able to view the picture in a more global manner. Unfortunately, however, at present there is still very little guidance for educators in selecting visuals that are appropriate for use with specific groups of learners.

In viewing the interactive effect between attributes of visual complexity and learner age level, Evans, Watson, and Willows (1987) indicated that an appropriate match between level of visual complexity and learner's age is important for the effective use of visualized materials. Nevertheless, for lack of complete and conclusive empirical evidence showing when to use one level of visual complexity or another, it is still difficult to ascertain if a specific visual presentation has too many or too few details for a particular child. Consequently, researchers in visual instruction have cited the need for continued research on the effects of varying visual complexity on cognitive learning across age levels (Dwyer, 1978; King, 1986; Hannafin, 1987).

Statement of the Problem

This study is designed to investigate whether, or to what extent, differences in the level of visual complexity in visual instruction have an effect on cognitive learning of students in different grade levels.

Specific questions related to the problem are as follows:

1. Are visuals with different levels of complexity differentially effective in facilitating student's comprehension of intended learning?
2. Does the addition of figure detail in visuals have an effect on students' ability to comprehend the intended visual learning?
3. Does the addition of background information in visuals have an effect on students' ability to comprehend the intended visual learning?

4. Do students of different grade levels differ in their ability to make use of the visual displays containing varied levels of complexity in terms of figure detail and background information?

Need for the Study

Visualized instruction has been recognized as an important instructional technique. Television, computers, interactive video, and an array of other educational media all heavily depend upon visuals to present learners the designated instruction. However, many researchers have found that the use of visuals to complement verbal instruction does not automatically increase the effectiveness of instructional materials (Dwyer, 1978; Levie & Lentz, 1982). Different visuals containing varying levels of complexity may have effects upon learning differently. Furthermore, a body of research data indicates that there are age changes associated with how children perceive visual stimuli (Barrett & Shepp, 1988; Gibson, 1969; Pezdek & Chen, 1982; Ritchey, 1982; Travers & Alvarado, 1970). As a result, selecting an appropriate picture for a given age group of learners becomes a critical issue for educators and instructional designers in designing instructional materials.

The existing research relating to these issues, however, has produced neither conclusive nor comprehensive results. Due to some methodological problems in research design, many studies have produced contradictory or not significantly different results on the effect of varying levels of visual complexity on cognitive learning (e.g., Borg & Schuller, 1979; Franzwa, 1973; Loftus & Bell, 1975; Moore & Sasse, 1971). In addition, the research literature is generally limited with regard to the effects of visual complexity on the lowest level of learning in the cognitive domain, such as identification, recognition, and recall (Cody & Madigan, 1982; Emmerich & Ackerman, 1976; Hurt, 1988; Jesky & Berry, 1991; King, 1986; Loftus & Bell, 1975; Nelson, Metzler, & Reed, 1974). Few research efforts have been devoted to the investigation of the effects of visual complexity level on children's higher-level cognitive processes, such as the comprehension of visual instruction. However, Bloom (1956) stated three decades ago that "...the largest general class of intellectual abilities and skills emphasized in schools and college are those which involve comprehension" (p. 89). Orlich et al. (1990) also indicated that comprehension was the real key to unlocking entry into the other higher-level cognitive behaviors, such as application, analysis, synthesis, or evaluation. Thus, in terms of practical applications, a sound investigation of the relationship between visual complexity and comprehension appears important as well as meaningful for the effective use of pictures in education.

Another limitation of the prior research concerning the effects of visual complexity on cognitive learning is the static visual stimuli invariably used as the material to be recognized or remembered. Although Dwyer (1970) examined the relative effectiveness of different visual stimuli via television, the essence of the visual instruction in the study was of a static rather than a dynamic nature. That is, the visual stimuli were only a series of static images transmitted via television (e.g., a videotaped slide presentation), instead of making effective use of the motion feature offered by the medium. Therefore, it is evident that there is need for investigating the effects of visual complexity on cognitive learning, when motion is a defining characteristic of a concept to be taught.

For lack of thorough and conclusive empirical evidence concerning effects of visual complexity on learning across age levels, teachers and instructional designers must rely on their intuition in deciding how to select and present visuals in instructional materials. Extensive empirical research needs to be conducted to further define the effects of visual presentations on achievement of learners in different age levels. Any simple-minded selection of visuals is unlikely to advance either the theory or practice of the design of visual instruction.

Overall, the significance of this study can be seen in the following three ways.

1. This study can provide new insights for understanding how visual information is perceived, stored, and comprehended, so that some psychological and educational implications can be extracted for the fields of instructional technology and psychology.
2. This study can generate empirically-based results about the effects of various levels of visual complexity on children's cognitive processes. As a result, educators and instructional designers would not need to rely on their intuition in deciding how to present visuals for learners at different ages.
3. This study can produce some guidelines for designing visual presentations across various media. Since level of visual complexity is not a physical attribute restricted within a specific medium, the findings of this study may broadly apply to learning from film, television, computer, interactive video, or multimedia systems.

Hypotheses

The focus of this study is to manipulate the levels of visual complexity in terms of figure detail and background information in order to determine whether added pictorial information in motion visuals facilitates children's comprehension of the intended learning. The following specific hypotheses are examined in this study.

1. There is no significant difference in the achievement of subjects taught the same learning content using three versions of video programs that differ in the levels of visual complexity (ie, outline drawings, outline drawings with added figure detail, outline drawings with added figure detail and background information).

2. There is no significant difference in the achievement of subjects in different grade levels taught the same learning content using three versions of video programs that differ in the levels of visual complexity.

3. There is no significant interaction between grade levels and three versions of video programs that differ in the levels of visual complexity.

Assumptions

The results of this study are based on several assumptions listed below.

1. The same grade subjects have similar prior visual experience. Their differences in visual experience

resulting from the socioeconomic background or other influences are overcome through random assignment.

2. The subjects have no specific pre-perception about visuals containing different levels of complexity.
3. The subjects complete both pretest and posttest in a serious manner and to the best of their ability.

Delimitations

The scope of this research study is delimited in several ways.

1. The subjects are restricted to the fourth and eighth grade students.
2. The learning content is restricted to the field of physical science.
3. The learning objective is limited to the comprehension level in cognitive learning domain.
4. The visual stimuli are all black-and-white.

Limitations

The following limitations should be taken into account before the results of this study are generalized in any way.

1. Since the present study utilizes only a limited range of age, the results can only be generalized within this age range.
2. Since the experimental treatments are short, the results may be affected by this time limitation.
3. Since the visual stimuli in three experimental treatments are all black-and-white, the results of this study can only be generalized to situation containing similar stimuli.

Definition of Terms

The following terms have been defined to clarify their use in the study:

Background information refers to the excess surrounding information in which the critical figure is embedded.

Cognitive domain of learning deals with the recall or recognition of knowledge and the development of intellectual abilities and skill (Bloom et al., 1956)

Comprehension refers to the ability to receive what is being communicated and make use of the material or idea being communicated without necessarily relating it to other material or seeing its fullest implication (Bloom et al., 1956).

Critical information refers to the objects and people that define the concept or are essential to the learning task. In this study, it especially means the information which is crucial to the narrative sense of the presentation.

Figure detail mainly involves the degree of shading and the number of embellishments within the critical objects and people of a visual.

Level of visual complexity is the density of information in a visual display (Peeck, 1987). It is defined in this study only in terms of two physical pictorial attributes-figure detail and background information. The confusing terms such as concreteness, realism, diversity, and explicitness are avoided in this study.

Outline drawings is one of the three video treatments in this study, which contains only the outline shapes of critical information necessary to convey the intentional meaning of the picture. Peripheral information such as interior detail in figures and background is entirely deleted.

Outline drawings with added figure detail is one of the three video treatments in this study, in which interior detail in figures is added to the outline drawings.

Outline drawings with added figure detail and background information is one of the three video treatments in this study, in which both figure detail and background information are added to the outline drawings.

Peripheral information includes those objects and people that call attention to but are not the critical ones. In the study, it especially means the information which is described in a complementary fashion as nonessential content.

CHAPTER 2
REVIEW OF THE RELATED LITERATURE

This chapter contains a review of literature relevant to the effect of visual complexity in motion visuals on children's learning. It is organized into the following subheadings: (a) effects of pictures on cognitive learning, (b) visual complexity, (c) attributes of visual complexity, (d) age of the learner, (e) visual complexity in motion visuals, and (f) summary.

Effects of Pictures on Cognitive Learning

Over the past several years, a number of empirical studies have been conducted in an attempt to determine the instructional value of pictures to learning (e.g. Dwyer, 1967, 1969, 1970; Brody, 1984; Haring & Fry, 1979; Lesgold, DeGood, & Levin, 1977; Levin, 1983; Paradowski, 1967; Spaulding, 1956) . In general, these studies have demonstrated that pictures can generate attention, arouse interest, provide additional or repetitive information, and enhance retention and comprehension of instructional materials. Peeck (1987) divided these effects into two broad categories: affective-motivational and cognitive functions. Since the present study focuses on cognitive learning, research concerning the cognitive roles of pictures is emphasized in this review.

Pictures are a versatile instructional tool; their positive effects on children's learning have been demonstrated on many learning tasks. Learning from prose is the one area that has received a considerable amount of research attention. Levin and Lesgold (1978) reviewed 12 studies on the effects of pictures on learning oral prose. Although the studies varied across methods for presenting the pictures (e.g., slides, booklets), the results clearly showed that the addition of relevant pictures had a significant positive effect on comprehension and recall of verbal information. For example, using different narrative fictional passages of varying lengths and complexities, Lesgold and others (1977) reported that first graders correctly recalled about 68% of the told stories with pictures and only about 47% without them.

In subsequent research, the instructional effect of pictures was also found in learning of nonfictional passages taken from newspaper (Levin & Berry, 1980). Fourth-grade students who listened to a series of newspaper stories accompanied by text-relevant illustrations remembered more of the information than did students who merely listened to the stories. The advantage of accompanying illustrations was consistent both when recall was tested immediately and a couple of days after the treatment.

In addition to the use of pictures in narrative prose learning, a large number of studies have focused on children's learning from illustrated text (Dwyer, 1975; Haring & Fry, 1979; Holliday, 1975; Hurt, 1987; Willows, 1979). Levie and Lentz (1982) reviewed 23 studies that produced a total of 46 comparisons of learning from illustrated text verse learning from text alone. With few exceptions, the results revealed that illustrations did facilitate learning the information in the written text that was depicted in the illustration. However, when the nonillustrated text information was tested, no learning effect was resulted from the addition of pictures. In other words, the effect of pictures on learning text varied with the pictures provided. Pictures with a high correspondence to the verbal message resulted in higher learning performance than those with a low correspondence. In normal instructional situations, Levie and Lentz pointed out that the addition of pictorial embellishments, which presented information that did not overlap the text content, would not enhance the learning of information in the text.

Similarly, the effects of pictures were also reported in studies regarding word recognition and speed of word decoding (Lippman, 1973; Willows, 1978). In a study in which third graders decoded words, Willows (1978) found that the degree of picture facilitation depended on three factors: the kind of pictures provided, word difficultly, and students' reading ability. For example, if the pictures were unrelated to the words to be decoded, then students' reading speeds were uniformly reduced.

As a result, according to the research literature on picture effect, it is evident that the use of pictures is not uniformly beneficial in all learning situations. The attributes present in a picture account in part for its effectiveness in serving an instructional task. A picture with improper physical attributes may not fulfill its instructional potential; in fact the intended learning task may actually be retarded or impaired by adding an improper picture.

In view of this perspective, many researchers have suggested that matching pictorial attributes to instructional functions could be considered an essential step for decisions about effective utilization of pictures in instructional materials (Hurt, 1987; Levin & Lesgold, 1978; Peeck, 1987).

Visual Complexity

A picture is a complex, multivariate medium, which is composed of various attributes. For example, the type of picture, its size, the presence or absence of color, and the density of information presented are among the attributes that have a profound influence on its effectiveness. Of these pictorial attributes, visual complexity, or the density of information contained, has been indicated by many researchers as a crucial factor in the visual learning process (Brody, 1984; Fleming & Levie, 1978; Hannafin, 1987; Levie & Lentz, 1982; Peeck, 1987; Travers & Alvarado, 1970). As Dwyer (1978), the principal contributor in this area of research, has stated:

> Even when appropriate visualization has been carefully selected to complement oral instruction, insignificant differences in student achievement may still occur because the visualization selected may contain either too little or too much information. Visuals containing small amounts of information may not be adequate to challenge the student and quickly cause him to become disinterested or bored. Visuals containing too much information may tend to overwhelm the student and cause him to withdraw from rather than engage in the necessary kind of interaction with the visualization which will enhance the learning experience. (p. 14)

In the literature, however, two opposite approaches to designing instructional visual materials have arisen from the concept of visual complexity. They are realism theories and relevant cue hypotheses (Angert, 1980; Dwyer, 1978; Hedberg & Clark, 1976; Parkhust, 1975).

Realism Theories

A number of early theorists studying audiovisual instruction suggested the existence of a realism continuum along which all materials could be scaled in relation to their instructional effectiveness. They believed that the closer the picture represented reality, the easier it was to remember and comprehend the information in the picture.

Dwyer (1972, 1978) collectively entitled this set of theoretic position as "realism theories." He defined realism in visual illustrations as "the amount of stimuli available to convey information to the student" (p. 5). Specifically, the realism theories included Dale's (1946) cone of experience, the iconicity theory of Morris (1946), Carpenter's (1953) sign similarity theory, and Gibson's (1954) theory of pictorial perception. Although these theories may differ with each other in detail, their basic assumption was consistent: realism in visual displays enhanced learning.

Dale's (1946) cone of experience was generally viewed as representative of the realism theories. Dale classified ways to present information on an abstract-to-concrete continuum ranging from abstract verbal symbol to direct purposeful experience. Some researchers have interpreted such classifications to mean that concrete, realistic materials were somehow better than abstract, simple signs. Learning would be more effective as the visual materials used more closely resembled their real-life referents.

Furthermore, with the introduction of videodisc and digital video technologies into education during the past few years, an increasing number of realism supporters have appeared among the instructional technology profession. The incorporation of complex and detailed visuals into instructional materials has been promoted since advanced media such as the videodisc can present information that is more realistic (Clark, 1989). These instructional designers believe that the most effective visual displays can be attained by cramming more details into pictures.

Relevant Cue Hypotheses

Relevant cue hypotheses represent the opposite position from realism theories regarding the designing materials in visual presentation (Dwyer, 1978; Miller, 1957; Travers, 1964; Travers & Alvarado, 1970). These hypotheses contend that realistic representations contain too many irrelevant details which may interfere with learning. Miller (1957) advised that it would be a mistake to assume that one cue added to another would increase learning by a linear increment. Travers (1964) also observed that human beings were capable of processing only a portion of the information available in complex events because their nervous systems had a limited capacity for handling information. In fact, Travers and others (1967) further pointed out that the learner's performance may be enhanced when visual presentations were reduced in amount of detail until only the cues relevant to learning were provided.

Angert (1980) indicated that the relevant cue position had its origins in information theory. According to this theory, humans are conceived of as an information-processing system which actively searches and extracts information from the environment through its various sensory systems (Broadbent, 1958; Fleming & Levie, 1978; Travers, 1984). The process of extracting vital information begins at the sense organs and ends at the highest level of the nervous system. Since the nervous system has very limited capacity for handling information, a certain kind of filtering takes place as information is transmitted from the sense organs to the nervous system. In general, only a fraction of information can be transmitted; the remainder is lost. Thus, Travers (1984) has suggested that the best way to present instructional materials is to contaminate them with as little irrelevant or superfluous information as possible, so that the relevant information could reach the nervous system rather than being filtered out.

Overall, relevant cue hypotheses argue that learners do not need highly embellished visual stimuli in order to comprehend the instructional materials. Visual displays used for instructional purposes should be simplified so that all irrelevant and superfluous information is expelled.

Definition of Visual Complexity

Wheelbarger (1971) indicated that the degree of complexity in a visual is an important variable for classifying visual illustrations. A review of the literature in visual education identifies a body of research studies that have been designed to investigate the relative effectiveness of visual illustrations possessing different degrees of complexity. However, the research devoted to this area has failed to establish a definition of visual complexity that is consistent. Researchers have employed diverse terminologies when referring to the same concept of visual complexity.

For example, Dwyer (1978) used the term "realism" in visualization to refer to a continuous variable that reflects the amount of detail in a picture. Visual illustrations can be classified along a realism continuum into eight types of pictures, ranging from realistic colored photographs to simple line drawings. On the other hand, other terminologies such as pictorial concreteness, pictorial detail, stimulus explicitness, and picture diversity are employed interchangeably by researchers to delineate the concept of visual complexity (Alesandrini, 1984; Arnold & Dwyer, 1973; Evertson & Wicker, 1974; Gorman, 1973; Ritchey, 1982; Snowman & Cunningham, 1976; Wohlwill, 1975).

In general, visual complexity can be simply defined as the density of information contained in a visual (Peeck, 1987). However, this definition should not be interpreted to imply that a single parameter of the visual stimuli, such as the number of elements portrayed, is sufficient to measure the level of visual complexity. Kreitler et al. (1974) and Angert (1980) have indicated that visual complexity is a multidimensional concept. The attributes along which the complexity of a picture is considered to vary may be more important considerations than the physical parameters when judging instructional effectiveness.

The complexity of a picture can vary among a great number of different attributes. However, there are two attributes which are indicated by most researchers as meaningful dimensions of visual complexity. They are the amount of interior detail in figures and the presence or absence of added background information (Dwyer, 1978; Fleming, 1987; Franken, 1977; Nelson, Metzler, & Reed, 1974; Spaulding, 1956; Travers, 1969). The stimulus set in the Nelson et al. (1974) study, for example, was developed conceptually on the basis of these dimensions. In the study, three experimental pictorial conditions were designed as: (a) photographs of naturalistic scenes, (b) unembellished line drawings of the central information of the photographs, and (c) embellished line drawings in which extra detail such as background context from the photographs was added. The same pictorial stimulus arrangement has been employed in many related studies (Cody & Madigan, 1982; Loftus & Bell, 1975; Pezdek & Chen, 1982; Pezdek, 1987; Ritchey, 1982). In the following section, research concerning these two attributes of visual complexity, interior detail in figures and background information, as well as their effects on cognitive learning, are reviewed in detail.

Attributes of Visual Complexity

There is substantial literature on the relationship between pictorial complexity and the learner's interpretation of information presented in pictures. In general, research indicates that the relationship between the amount of pictorial complexity and the level of student achievement is curvelinear, indicating that it is subject to an optimal-level principle (Dwyer, 1978; Wohlwill, 1975). In other words, on either side of an optimum point, visuals containing too much or too little instructional stimuli influence student learning adversely.

These findings underscore the need to investigate some questions relating to visual complexity. One question relates to means whereby the amount of information included in a visual could reach the optimum level for instructional functions. Another is whether the attributes of visual complexity, e.g., interior detail in figures and background information, make a difference in the process? Following is a review of selected empirical research that addresses these questions.

Amount of Interior Detail in Figures

In a visual display, critical figures (objects or people) may show extreme variations in amount of interior detail. The range is from full color photographic representations to black-and-white outline drawings that portray only the few edges the artist considers to be of crucial significance in identifying the characters. In some studies, researchers have directly manipulated the amount of figure detail in pictures to determine whether extra interior detail facilitates different levels of learning in the cognitive domain. Perhaps the most significant work in this area was a series of studies undertaken by Dwyer (1978, 1982-83) .

Since 1967 Dwyer and his associates have conducted more than 100 separate studies to investigate the effects of representational pictures that varied in the amount of figure detail on cognitive learning. Dwyer (1982-83) reported that approximately 40,000 college students and 8,000 high school students have been involved in these studies.

The instructional unit used in the studies consisted of a 2,000-word text about the anatomy and physiology of the human heart and a set of 37 illustrations prepared in eight variations of complexity: simple line drawings, detailed shaded drawings, photographs of models of the heart, and photographs of heart specimens. Each type of visual has been produced in both black-and-white and color. To determine which treatment most effectively facilitated cognitive learning, four criterion measures were developed. They were a drawing test, an identification test, a terminology test, and a comprehension test.

Results of these studies showed that all types of visuals were not equally effective in facilitating student achievement when instruction was externally paced. The simple line drawing presentations emerged as the most effective on the total criterion measure. The more detailed visuals (i.e. the shaded drawings and colored photographs) were least effective in supplementing verbal instruction. In fact, they were no more effective than verbal instruction alone. In Dwyer's (1978) own summary of his studies, he concluded that very detailed visuals were interesting to see, but they had limited instructional functions. Dwyer stated, "[Humans] possess a limited information processing capacity, and merely increasing the amount of information presented to learners in an instructional situation will not automatically increase their learning of the content material" (p. 22).

On the whole, the results of these studies by Dwyer and his associates appear to be consistent with the relevant cue hypotheses. Employing highly detailed, complex illustrations in visual lessons is unnecessary, and it may even impair the intended learning.

Although Dwyer and his associates have carried out extensive work on visual instruction, there appears to be a limitation in these studies. That is, all the subjects involved in the research were restricted to college and high school students. No middle schoolers or younger children were investigated. However, most research has indicated that the most significant problems with interpretation of visual images were usually found in populations of younger children rather than adults (Hurt, 1988; Travers & Alvarado, 1970). Therefore, in terms of practical applications, it seems that Dwyer's research results are restricted to some extent.

In addition to Dwyer's investigation of specific learning tasks, some researchers have focused on the roles that varying levels of figure detail play in concept formation. Using two black-and-white slide presentations with different amount of detail, Gorman (1973) studied the effects of pictorial detail on concept learning by students at the fifth, ninth, and fifteenth (college juniors) grade levels. One set of slides employed simple line drawings, while the other set used detailed drawings. The stimulus materials selected in the study were three meaningful architectural concepts-perpend, squinch, and mastaba. A simplified yes-no response test was used to determine whether the subjects could recognize exemplars correctly. The results of this research indicated that there were no significant differences in the final performance of any of the groups. Gorman acknowledged that the lack of significant difference was attributed to an insufficient amount of irrelevant detail in the detailed drawing format. The author suggested that "apparently, a tolerance level exists for some irrelevant detail in a picture" (p. 345). However, further investigations are still needed on such questions as "if a tolerance level for some irrelevant detail in a picture exists, then what are its limits? Is the tolerance level the same at different grade levels or does it vary?" (p. 349).

Another researcher using science materials found that supplemental line drawings helped high school students learn new concepts (Holliday, 1975). Eighty tenth-grade students were randomly assigned to two instructional treatments: verbal statement and verbal statement plus simplified line drawings. The instructional materials described the effects of a plant growth hormone on stem and root growth. Results of this study revealed that there was a significant difference in favor of students who were presented line drawings adjunct to verbal description. Since no other types of picture were employed in the study for comparison, Holliday recommended that instructional designers in science education should continue to explore this issue.

On the whole, the above studies primarily investigate the effect of variations in figure detail on such cognitive learning tasks as identification, comprehension, and concept learning. However, another group of research has focused on this effect on picture memory. A review of these studies is provided below.

Effect of Amount of Figure Detail On Picture Memory

In an early study, Travers (1969) conducted an experiment to determine the effect of redundant cues on the recognizability of an illustration. Second- and fourth-grade children and college undergraduate students were instructed to identify common objects at three levels of interior detail: outline drawings, detailed drawings, and shaded drawings. Travers found that the addition of detail and shading to outline drawings increased the recognizability of presented pictures.

Evertson and Wicker (1974) investigated paired-associate learning by young children and reported that the retention of visual stimuli was positively related to the amount of detail in the stimuli. In their study, four and seven year-old children studied the pairs of real objects, color photographs, or black-and-white line drawings under the conditions of either visual elaboration or verbal elaboration. The results revealed that objects and photographs both surpassed line drawings in terms of recall. Evertson and Wicker concluded that pictorial detail, or pictorial concreteness, appeared positively related to learning with young children.

In a similar study of the role of stimulus concreteness in children's pictorial paired-associate learning, Snowman and Cunningham (1976) provided support for Evertson and Wicker's notion of a concreteness continuum. In the study, ninety-nine preoperational stage children learned 24 pictorial paired-associates at one of three levels of concreteness: low detail line drawings, high detail line drawings, and high detail line drawings with a verbal prompt. The difference between the low detail and high detail line drawings was that the non-criterion details were totally deleted from the former drawings. The results of this research indicated again that increased pictorial concreteness (interior detail) did result in increasingly higher level of picture recognition. However, Snowman and Cunningham advised that subject's cognitive stage was another variable involved in the study which required further investigation.

A more recent research by Jesky and Berry (1991) explored the effect of the interaction between various degrees of visual detail and cognitive style on pictorial recall memory. The stimulus materials used in this study were three sets of slides of common household items, each composed of three different treatment versions of the same image. One rendered in photographic color, another in a black and white photographic format and the third in a line drawing format. The findings indicated that recall was related to the pictorial details. More detailed visuals facilitated recall better than did less detailed or complex materials.

In contrast to the previous findings, other researchers have found that the amount of figure detail contained in pictures did not appear to influence learner's picture recognition memory. In an earlier study, Franzwa (1973) investigated the effect of picture detail on visual retention. One hundred and twenty three college students perceived animal pictures in either color photographs or black-and-white line drawings. The data revealed that figure detail did not produce a significantly higher score in the recognition test.

Nelson, Metzler, and Reed (1974) examined the role of interior detail in long- and short-term recognition of pictures and verbal descriptions. Four stimulus conditions were presented to college students: (a) photographs of naturalistic scenes, (b) verbal descriptions of the main theme of the photographs, (c) unembellished line drawings of the central information of the photographs, or (d) embellished line drawings with extra details from the photographs. Results indicated that subjects performed better in the three picture conditions than in the verbal description one, but the performance was not significantly different among the visual stimuli conditions. This finding implied that the better recognition memory for pictures than for verbal description was not due to the extra details in pictures.

Nelson and others proposed a conservation of processing hypothesis to explain the research findings. That is, subjects could only store a constant amount of information about a picture in a fixed amount of processing time; hence, their performance would not be affected by the number of extra details added in a picture.

However, in reviewing this study, it should be noted that the percentages of correct short-term recognition in the three picture conditions were all around 98%. Thus, it may be assumed that the lack of performance difference in various amount of pictorial detail could be attributable to a ceiling effect.

Loftus and Bell (1975) employed the same stimuli used by Nelson et al. and conducted another recognition experiment. They found no difference between the two levels of drawings, but the photographs were superior to both drawing formats. Loftus and Bell referred to this finding as unexpected and acknowledged that their results were difficult to reconcile with those of Nelson et al. (1974).

A more recent study on the effects of pictorial detail on recognition was conducted by Cody and Madigan (1982). The study was similar to that of Nelson et al., with some degree of modification in visual stimuli. In the study eighty common objects were produced in three formats: typed words, black-and-white line drawings, and color photographs. The photographs were objects embedded in a natural setting. The drawings were produced by tracing rear-projected photograph slides and omitting color and any background detail. Each college subject viewed the study slides in one of the formats. Two recognition tests were administrated immediately after the study phase and two days later. The results supported the Nelson et al. findings, that pictures were remembered better than words, regardless of the number of picture details. Recognition performance for photographs was equal to that for drawings. Cody and Madigan concluded that "the most important factor affecting retention is the type of feature encoded and not how many per se. Pictures directly access semantic information but additional details of color or realism of photos versus drawings are not important for recognition" (p. 27).

However, a consideration that should be made concerning this study is that although Cody and Madigan employed the same visual stimuli used by Nelson et al., due to the modifications the two picture treatments actually involved three separate attributes of visual complexity. They were amount of figure detail, presence or absence of background information, and color. Therefore, it cannot be determined what variables or what interactions among them actually resulted in the lack of significant differences between the pictorial conditions.

In a later study, Ritchey (1982) continued to clarify the issue of pictorial detail and memory by using a stimulus set based on a simple information continuum, which was also similar to that used in the Nelson et al. (1974) recognition memory study. Materials used in the study were 54 common items which were prepared in each of three different formats: name only, line drawing, and outline drawing. Outlines were produced for each picture by making a simple tracing of the figure-ground border of the line drawing. Subjects consisting of third graders, sixth graders, and adults were presented with the items in each of the three formats. Ritchey's research indicated that outlines were recalled significantly better than detailed drawings and that both of these were recalled better than words. However, the finding in this study contradicted the assumption proposed by Ritchey and Beal (1980) who hypothesized that greater picture detail led to better recall. Explanations for the present results suggested by Ritchey were that an outline provided a more unique experience, resulting in the formation of a memory trace that was more distinctive than that produced by a conventional detailed drawing. Ritchey concluded that any explanation needed further research on understanding how memory worked.

Presence or Absence of Background Information

The influence of background information on cognitive learning is another major focus of the research on visual complexity. Many researchers have indicated that perception of a visual figure was determined not only by its characteristics but also by its surrounding context (Antes & Metzger, 1980; Fleming, 1987). Fleming and Levie (1978) pointed out the importance of background information by stating that "a pictured object can be made more or less salient by removing or adding a competing background" (p. 112).

In general, the background information refers to the surrounding information in which the critical figure is embedded (Borg & Schuller, 1979; Fleming & Levie, 1978; Sparks, 1973). If the critical object of a picture is a rider pedaling into a strong wind, for example, extraneous embellishments such as pedestrians, buildings, and trees along the road are all included in the background information of the picture; only the rider, the bicycle, and the wind are designated as the critical figures.

According to this definition, pictures may vary in the extent to which the critical figure in the picture is presented in context or in isolation. However, a picture of a figure embedded in an environment presents a different visual task from a picture of an isolated figure. As Travers (1969) stated, "the presence or absence of settings represents a dimension involving the amount of information presented and also a dimension related to the number of stimuli that may distract attention from the central object of interest" (p. 29). In addition, Franken and Davis (1975) and Franken (1977) also suggested that figure-ground represented the organization of a picture and it was an important factor influencing visual processing performance.

The presence or absence of background information in a visual has been the subject of a number of empirical investigations. One of the earliest reported studies concerning the influence of background information was conducted by Spaulding (1956). He examined the communication potential of various illustrations and found that poorly educated adults in several countries had difficulty in interpreting pictures with poor figure-ground quality. According to Spaulding, visual information unnecessary to critical figures should be eliminated because it may motivate an interpretation that is not compatible with the purpose of the illustration.

In a more recent study of use of background information in a filmstrip/tape instructional program, Borg and Schuller (1979) reported that the employment of complex art contributed nothing to either the learner's performance or to his/her attitudes toward the lessons. In their study, eighty adults were randomly assigned to either a simple or a complex audiovisual lesson format to determine the effect of excess details on mastery of instructional material. The audio parts of the two versions were identical, but the visual art on the revised filmstrip was simplified by removing background and other superfluous items. Results revealed that there were no significant differences between the two groups in achievement. However, Borg and Schuller suggested that if a greatly simplified set of visuals was produced, the results might have favored the very simple version over the complex one.

Whitaker and Sullivan (1980) investigated the effects of narration and level of background information on children's recall of illustrated materials. Third- and sixth-grade students viewed slide/tape stories in which the pictures were produced with two levels of background information. The high detail line drawings were made directly from an adapted book, while the low detail line drawings were simplified by tracing the outline shapes of the major figures and deleting the extraneous items. The results of this study were not as conclusive. Low detail pictures facilitated recall better than high detail pictures on the immediate test; however, the effect was not present on the delayed test. Whitaker and Sullivan suggested that further research on this issue should help increase an understanding of the effects of picture characteristics on memory for audiovisual materials.

In contrast to Whitaker and Sullivan's findings, Antes and Metzger (1980) reported that the context (background) of objects helped learners construct a general characterization of the pictures which provided learner expectancies to perform their discrimination task. In the study, undergraduate subjects viewed either a line drawing containing target objects with surrounding context or an array of objects without context. On completion of viewing, subjects were asked to distinguish the target object from three distractors. Results indicated that objects in the context treatment were recognized better than those in the no context treatment only when incorrect response alternatives were inconsistent with the picture context.

The outcomes of another study on figure-ground perception by Franken (1977) provided evidence supporting the idea that figure-ground quality in a picture was a major variable governing picture-recognition performance. Franken defined a picture with high figure-ground quality to be a display in which critical information was salient from the peripheral (background). In addition, this research also indicated that figure-ground perception improved with age. In the study, subjects in five age groups (5.9, 6.9, 8.9, 12.8, and 21.9 yr.) were presented with pictures in either high or low figure-ground qualities. The result showed that subjects recognized better with pictures which had high figure-ground quality and there were developmental effects in picture-recognition memory.

Age of the Learner

The above mentioned studies not only reveal inconsistencies about the instructional effects of visual complexity on cognitive learning, but also suggest that these effects interact with learner age. Travers and Alvarado (1970) have indicated that somewhere between infancy and adulthood, most persons learn to use pictorial material effectively. In addition, research on cognitive development and selective attention also has established that the ability to process information in a visual improves with age (Collins, 1970; Hagen, 1972; Hale & Taweel, 1974; Pick, Christy, & Frankel, 1972).

According to Piagetian theory (Flavell, 1977; Wadsworth, 1984), for example, young children tend to select details in a picture without much concern for whether they are central to the theme of the picture. However, as the children grow older, their capacity of handling complex visual stimuli and their tendency to interpret the material as a whole increase. They can easily restrict their attention to the essential information and ignore information that is peripheral.

Such age differences in visual performance have been observed in many developmental studies. Two areas of study that especially relate to the present study are: (a) the learner's selective attention, and (b) the learner's ability to process pictures of varying amounts of complexity.

Selective Attention

Lorch and Horn (1986) defined selective attention as "the efficient use of task-relevant information without disruption by irrelevancies" (p. 184). One of the consistent research findings in this area is a developmental trend toward greater flexibility in deploying attention. Older children have been found more capable of selectively attending to the relevant stimuli than younger children.

Collins (1970) provided empirical evidence supporting this developmental position. In this study 168 third-, sixth-, seventh-, and ninth-grade students were tested for learning of essential (critical) and nonessential (peripheral) content from a film presentation. It was hypothesized that learning of central content should increase with age up to an asymptote, while learning of peripheral content should increase up to early adolescence and decrease thereafter.

Results supported the investigator's original hypothesis. Preadolescent children were readily distracted from the essential learning cues by responding more actively to peripheral detail. They tended to take in increasingly more environmental information, without regard for the relative value of the different informational inputs. In contrast, older children tended to attend selectively to the many information inputs that confronted them. They were capable of focusing on certain parts of visual information while ignoring other parts. Thus, Collins concluded that there did exist a developmental increase in ability to process visual information.

In a similar study of age differences in children's selective learning, Hale and Taweel (1974) also found that only until adolescence did children show the efficient use of selective attention as a characteristic approach to a learning task. In the study, children of ages 5 and 8 years were given three learning tasks: one component selection task and two incidental learning tasks. A posttest, which measured the children's recall of information about each component (shape or color) in the visual materials, was assumed to reflect the degree of attention directed to each component in stimulus materials. Analysis of the study results indicated that as children grew older, they would show more capacity to accommodate the visual demands of a learning task.

A series of experiments by Hagen (1972) again indicated that with increasing age, children became better able to allocate their attention to a central task in a visual task situation. In the first experiment, first-, third-, fifth-, and seventh-grade subjects were given two learning tasks: a central task of remembering the picture locations in a series of cards, and an incidental task of remembering the picture colors. Central memory task performance was found to increase with age, whereas the incidental performance did not and actually declined for the seventh graders. In subsequent studies, Hagen and his colleagues replicated the earlier findings. Furthermore, they found a positive correlation between central and incidental task performance at the younger grade levels, but a negative correlation at the older grade levels.

Overall, Hagen's research suggested that there were age differences in how the children allocated their attention. Obviously, children by seventh grade had acquired the ability to selectively focus their attention on the relevant cues of the stimuli and ignore the irrelevant ones.

In a quite different study by Pick, Christy, and Frankel (1972), the evidence suggested a similar conclusion that older children were more able to filter out irrelevant information than younger children. Second and sixth graders were presented various pairs of visual stimuli under preinformed and postinformed conditions. In both conditions, the subjects were asked to judge the paired stimuli to determine whether they had the same characteristics, such as shape, color, and size.

The results of this study revealed that children improved in their ability to focus attention exclusively on relevant information when they had knowledge of the relevant information. It was also suggested that complexity of visual stimulus affected the way in which information was perceived and recalled. In general, the younger children required more time to judge the shapes than they did the colors.

Visual Complexity Processing

Developmental studies have also focused on the relationship between the complexity of a picture and a child's ability to process it. Unfortunately, the research results thus far are mixed and usually contradict one another.

Moore and Sasse (1971) used subjects at the third, seventh, eleventh grade levels to study the effects of pictorial complexity on immediate recall of picture contents. In the study, a total of 9 pictures were selected under three levels of visual complexity: line drawing, painting, and photograph. These researchers found that there was a significant difference in the mean scores for types of picture across grade levels. At grades seven and eleven line drawings had the highest mean scores, while painting had the highest score at the third grade level. Photographs were the least effective visuals at all grade levels.

However, it should be noted that there exist several methodological problems in the study. First, each level of visual complexity contains only three pictures as the visual stimuli. Second, although every picture is selected based on the same proposed criteria, the content contained in each picture is absolutely distinct. A more effective approach to investigating this research problem would be to keep each picture content constant. Finally, because all questions about the picture content are programmed into the timed slide presentation (15 seconds for each multiple choice question), each subject is forced to answer them at the same rate. Owing to these problems inherent in the research design, results from the study may have limited generality.

In a more recent study of young children's ability to interpret pictures with varying amount of complexity, Hurt (1988) reported that the least complex pictures were the most effective way to achieve the intended instructional function. A group of 155 first-grade students were shown 12 black-and-white pictures containing three levels of resolution and two levels of background information. The stimulus materials in the study were either photographs or computer-generated graphics which included computer scans and computer drawings. Research results indicated that first-grade students were able to recognize the critical objects in both computer-generated (less complex) and camera generated (more complex) pictures, but the peripheral objects were more easily recognized in low-resolution computer drawings. Hurt concluded by suggesting that "pictures with as little unimportant detail and background as possible appear to promote more complete interpretation" (p. 110).

Contrary to the above findings, Evertson and Wicker (1974) reported a different developmental trend in processing visual information. In the study, three types of visual stimuli such as line drawings, color photographs, and objects were used as elaborative prompts in paired-associate learning with 4- and 7-year-olds. The results revealed that photographs and objects were associated with more learning than line drawings at both ages. Evertson and Wicker explained the reason was because of younger children's lack of visual literacy to interpret such symbols. They also predicted that the interaction effect between visual types and age level might become significant if a wider age range had been employed. However, they concluded that pictorial detail appeared positively related to greater learning and that this relationship would be stronger with younger children than with older ones.

Pezdek and Chen (1982) conducted two experiments to examine the developmental differences between adults and children in recognition memory for visual details in pictures. A total of 60 subjects were selected from three age groups-second-, fourth-graders, and college students. They were presented a series of complex and simple line drawings used by Nelson et al. (1974). The simple and complex forms of each picture contained the same central information, but peripheral details, such as shading and embellishment were added in the complex form of each picture. A same-different recognition test followed in which the distractor items were original pictures from the presentation phase with the amount of physical detail altered.

Posttest results indicated that the second- and fourth-graders were similarly sensitive to pictures in the simple and complex presentation conditions, while the adults were more sensitive to pictures in the simple than the complex presentation condition. Since the results concerning adult performance were inconsistent with previous findings (Nelson, Metzler, & Reed, 1974), Pezdek and Chen conducted a second study to test the replicability of the adult data in the first experiment. The findings clearly replicated the adult data from the first experiment.

Although the adult data was inconsistent with previous relevant findings, Pezdek and Chen proposed an explanation that adults were more likely than children to thematically encode the pictures. Thus, adult subjects more accurately recognized pictures in the simple presentation condition than in the complex one. The authors concluded that, on the whole, processing physical information in pictures was developmentally different.

In continuing the research, Pezdek (1987) conducted a life-span study of the role of visual complexity. This study assessed the effect of the amount of pictorial detail on picture recognition for 7-year-olds, 9-year-olds, young adults, and older adults over 68. Subjects were presented with simple and complex line drawings, and then with a same-different recognition test.

Results indicated that across all four age groups, pictures presented in their simple form were recognized more accurately than pictures presented in their complex form. Pezdek interpreted the results by stating that "pictures, like prose materials, are processed schematically" (p. 812). Visuals (e.g., simple line drawings) that communicated only scheme-relevant information in pictures were more likely to be encoded and retained in memory than visuals that communicated more scheme-irrelevant information (e.g., complex line drawings).

Visual Complexity in Motion Visuals

Learning may not always benefit from the addition of motion in a visual presentation. Yet, when motion is a defining attribute of a concept to be learned, researchers find that it is better to present it by motion visuals than by a simulated motion medium such as slides or filmstrips (Allen & Weintraub, 1968; Houser, Houser, & Mondfrans, 1970; Spangenberg, 1973).

Unfortunately, most research pertaining to the effect of visual complexity on cognitive learning has used static stimuli as the material to be learned. Few studies have investigated the relative effectiveness of motion visuals that employ different amounts of visual complexity to complement verbal instruction. In this section, the studies on this issue are reviewed.

One important early study was conducted by Carpenter (1954). In the study two filmographs were prepared from a sound motion picture film concerned with riot control for military trainees. One was based on frames of the original motion picture; the other was shorter and based on stock photographs that were substituted for complex mob scenes. Achievement gained and attitudes of subjects seeing the two filmographs were about the same. Carpenter concluded that simplified visual presentations in the motion picture format were about as effective as the more complex ones.

Dwyer (1970) utilized the human heart visual materials to examine the relative effectiveness of different types of visual stimuli via television. One hundred and fifty-seven college students were randomly assigned into five treatment groups (oral, simple line drawings, detailed and shaded drawings, photographs of a model, and realistic heart photographs). Each visual treatment contained 39 black-and-white slides which were videotaped and then presented via television. The results of this study indicated that all types of visual treatments were equally effective in promoting student achievement. Dwyer concluded that "merely increasing the amount of realistic detail in visual illustrations in a linear fashion does not proportionally increase S [subject] achievement" (p. 46).

However, in reviewing this study, it is worth noting that the visual instruction Dwyer designed in the study was a videotaped slide presentation rather than a real television lesson. The visual material was of a static rather a dynamic nature. Motion visuals, such as a video segment of the internal processes occurring during the systolic and diastolic phases of the heart, were not compared with other visual presentations at different levels of complexity.

Recently, with the increasing use of computer animated graphics in school settings, a number of researchers have employed computers to study the effects of visual complexity in motion visuals. Acker and Klein (1986) designed three 30-second spatial transformation tasks in both video and computer animation to investigate the relationship between visual complexity and spacial learning. A total of 98 third graders, middle schoolers, and adults participated in the study.

The result demonstrated that the less detailed version of the learning tasks (displayed in computer animation) was more effective than the detailed version (displayed in video) for the older students, while no performance differences were found between two visual versions for younger children. Acker and Klein suggested that "media productions targeted for older students...should avoid superfluous detail included in the name of realism" (p. 29).

Employing the same instructional media-video and computer graphics, Hozaki (1988) investigated the effects of levels of visual complexity and cognitive styles upon performance in a lesson of paper folding. Three levels of instructional modes used in this study were no visuals (text only), simple line drawings, and realistic visuals. Although paper folding was a psychomotor task, Hozaki measured two different categories of learning outcomes in the study. They were physical performance of paper folding (psychomotor domain) and mental comprehension of paper folding (cognitive domain).

The general findings based on the college subject's physical performance test were that learners taught by realistic visuals performed better than those taught by simple line drawings and by no visuals, even when learners were allowed to repeat the visual instruction during the lesson. Regarding subject's mental comprehension, instructional modes did not make any significant difference.

In this study, it should be noted that the differences between the two visual modes are manifested not only in the level of visual complexity, but also in the nature of continuity. The realistic visuals mode is a videotaped demonstration of the whole paper folding process by human hands. In contrast, the simple line drawings mode is a series of computer-generated still graphics which only show each complete step of paper folding. When receiving instruction from this mode, the subjects have to mentally "fill in" the missing images between each step. Thus, it is logical to conclude that the superiority of realistic visuals in this study may be attributed to its continuity rather than the addition of visual detail.

In a similar study of the video and computer graphics, Chou (1991) investigated the effects of visual information presentation mode and testing mode on skill analysis training. One hundred and five college students received visual instruction on the long jump presented by either realistic video or animated simple computer-generated line graphics.

Results indicated that the presentation mode and testing mode did not contribute to a significant differences in learner's discriminative performance. However, students who received instruction from computer graphics and were tested in video significantly underperformed students who received the same instruction and were tested in the same visual mode. The implication of these findings was that learners may have difficulty in transforming what they learned from instruction in simple line drawings to a test in a more realistic presentation.

Summary

Pictures are a versatile instructional tool. Their positive effects on children's learning have been demonstrated on many learning tasks, such as oral prose, written text, and word recognition (Levie & Lentz, 1982; Levin & Berry, 1980; Levin & Lesgold, 1978; Willows, 1978). However, research of visual instruction show that the inclusion of a picture in instruction does not automatically improve student achievement (Dwyer, 1978; Levie & Lentz, 1982; Peeck, 1987). Different visuals containing different amount of visual complexity may affect learning differently.

The complexity of a picture can vary among a great number of different attributes. Two attributes have been recognized by researchers as important factors influencing learner's processing of visual information (Dwyer, 1978; Fleming, 1987; Nelson, Metzler, & Reed, 1974). They are the amount of interior detail in figures and the presence or absence of background information.

In a visual display, critical figures may show extreme variations in amount of interior detail. The range can be from full color photographic representations to black-and-white outline drawings. A number of researchers have directly manipulated these variations to determine whether extra interior detail facilitates learning in the cognitive domain (Cody & Madigan, 1982; Dwyer, 1978; Franzwa, 1973; Gorman, 1973; Nelson, Metzler, & Reed, 1974; Ritchey, 1982). In general, this research shows that the addition of figure detail to a picture does not improve student's learning of the content material. In some studies, the simple line drawings even emerge as the more effective way than the complex ones in presenting the intended visual information. However, further research is still needed to determine the influence of the addition of figure detail on cognitive learning.

The influence of background information on cognitive learning is another focus of the research on visual complexity (Antes & Metzger, 1980; Borg & Schuller, 1979;

Franken, 1977; Spaulding, 1956; Whitaker & Sullivan, 1980). Unfortunately, the research results thus far are inconclusive and usually contradict one another. Thus, it is still unclear whether the addition of background information in a picture provides learners more visual cues or it distracts learners' attention from the critical information.

While the research indicates that visuals containing varying levels of complexity have different effects upon learning, many researchers find that these effects interact with learner age. A number of empirical studies have been conducted which attempt to establish the relationship between the complexity of a picture and a child's ability to process it (Collins, 1970; Evertson & Wicker, 1974; Hagen, 1972; Hale & Taweel, 1974; Moore & Sasse, 1971; Pezdek & Chen, 1982; Pezdek, 1987). Although the research results appear inconsistent to some extent, in general, researchers agree that there are age differences in how the children allocate their attention to a visual task. Only until adolescence can children acquire the ability to selectively focus their attention on the relevant cues of the visual stimuli and ignore the irrelevant ones.

In reviewing the studies concerning the effect of visual complexity on learning, it is evident that they frequently have used static visual stimuli as the material to be learned. Only a few studies have attempted to investigate the relative effectiveness of motion visuals that employ different levels of visual complexity to complement verbal instruction (Acker & Klein, 1986; Chou, 1991; Dwyer, 1970; Hozaki, 1988). In view of the increasing use of motion visuals in school settings today, there is no doubt that more research work needs to be conducted regarding this area.

CHAPTER 3
METHODOLOGY

This study was designed to investigate whether variances in the amount of visual complexity in motion visuals had an effect on children's learning. The amount of figure detail and background information were two attributes of visual complexity examined. In addition, different age groups were selected to determine whether the effect of visual complexity interacted with learner age.

Research Design

A 3 × 2 factorial, pretest-posttest design was used for the study. There were two independent variables. The first one was visual complexity which consisted of three levels: (a) outline drawings; (b) outline drawings with added figure detail; (c) outline drawings with added figure detail and background information. The second independent variable was age of the students. Two age levels, fourth graders and eighth graders, were tested.

Subject Selection

Research on selective attention has identified that young children by the age of ten had greater difficulty in selectively focusing their attention on the essential learning task than did adolescent children (Collins, 1970; Hagen, 1972; Hale & Taweel, 1974). Therefore, the subjects selected for this study consisted of fourth-grade and eighth-grade children. Three fourth- and 3 eighth-grade classes were drawn from two public schools in a county school district in north central Florida. The average percent of students by race and sex in these two schools was as follows: 71.5% white, 24.5% black, 1.5% Hispanic, and 2.5% Asian; 50% male and 50% female.

The three classes in each grade level were randomly chosen by the school principals and the school curriculum coordinators. All of the classes selected were average classes and were similar to one another in their academic achievement.

In each selected age group, attempts were made to create groups with equal numbers of males and females for in each treatment. However, gender was not specifically controlled for this study because research has indicated that boys and girls in the same grade level learned equally well from illustrations with various levels of complexity (Dwyer, 1971b).

Prior to any contact with the subjects in both grade levels, parents were sent parental consent forms that described the research purpose, time required, and procedures involved. Only those subjects whose parents signed the consent form were included in the study. Approval for the use of human subjects in this study was granted from the University of Florida Institutional Review Board.

Experimental Materials

Instructional Content

The instructional content used for this study was a video lesson concerning the motion of objects in the universe. The main reason for selecting this content material was that movement was a defining attribute of the concept taught in this lesson. In the literature, it has been suggested that learning can benefit from the addition of motion in a visual presentation only when the particular content to be learned consists of the motion itself and its characteristics (Allen & Weintraub, 1968; Houser, Houser, & Mondfrans, 1970; Spangenberg, 1973). Since the selected instructional content complied with this condition, the use the motion visuals in the present study could be fully justified.

The 14-minute instructional video lesson in this study was further divided into three units: (a) motion and force, (b) gravity, and (c) the law of inertia. In each unit, a related question was first posed, and then the basic concept as well as some real-life examples of this concept were explained and demonstrated.

The reason for posing questions in each unit was that questioning has been indicated by many researchers as an effective strategy in teaching science (Harlen, 1991; Jacobson & Bergman, 1991). They found that posing questions would stimulate and lead children into inquiry, which was a precious quality in learning science concepts. Furthermore, in examining techniques for improving classroom teaching, Good and Brophy (1987) also found that questioning was a successful strategy for stimulating student motivation to learn. Questioning could help put students into an active information-processing or problem-solving mode.

The employment of real-life examples in the design of the video lesson was in accordance with the research on instructional design and motivation. It has established that students were likely to be motivated to learn things that were meaningful and related to their existing experiences and knowledge (Davis, Alexander, & Yelon, 1974; Good & Brophy, 1987; Wlodkowski, 1984). To make a lesson meaningful and relevant to students, Good, Brophy, and Wlodkowski all suggested that the use of daily-life examples in the instruction would be an effective strategy for heightening student involvement and for limiting indifferent learning. Therefore, despite the short length of the video lesson to be used in this study, it was certain that the video lesson could engage students actively by using various real-life examples.

The instructional content of the video lesson was developed by the author with reference to several science textbooks (Abruscato, Fossaceca, Hassard, & Peck, 1980; Brockway, Gardner, & Howe, 1985; Moche, 1977; Shalit, 1981; Sund, Adams, & Hackett, 1980). During the development of the lesson content, the difficulty level was reviewed periodically by practicing teachers of fourth and eighth grades as well as professors teaching science education at the University of Florida. With respect to the reading level, this lesson content was designed in terms that both fourth and eighth grade students could easily understand the instructional material. Since the reading ability of fourth graders was lower than eighth graders, the narration of the instructional program was written on the basis of fourth grade level.

Instructional Treatments

The video instructional treatments for this study were produced in two phases. In phase one, three versions of black-and-white computer animation were created using the ADDmotion animation program that runs on a Macintosh environment. ADDmotion was chosen because of its ease of use and impressive capabilities for creating animated sequences. In addition, ADDmotion has been designed as a media integration toolkit for a popular authoring software program, HyperCard. However, one of the serious problems in ADDmotion was the way of managing computer memory. Although recommended minimum memory for ADDmotion in black and white mode was 2 MB, in actual use, 8 MB of memory were suggested by the author for an animation file which was more than 250K bytes (about 1 minute 15 seconds to 2 minutes depending on the size of visuals). If ADDmotion was running in a low memory situation, unpredictable consequences occurred from time to time.

After the three versions of computer animation had been produced, the next phase was to convert them to be three VHS videotapes by recording the image from a computer monitor with a professional studio camera. These videotapes represented three different levels of visual complexity in motion visuals for this study: outline drawings (OD), outline drawings with added figure detail (ODF), and outline drawings with added figure detail and background information (ODFB). Although the three versions of the video programs had different levels of visual complexity, they all employed the identical verbal narration to complement the visual information.

In the OD version, the computer animation contained only the outline shapes of critical objects necessary to convey the intentional meaning of the picture. Peripheral information, such as figure detail and background, was not included (see Figure 3-1). This version of computer

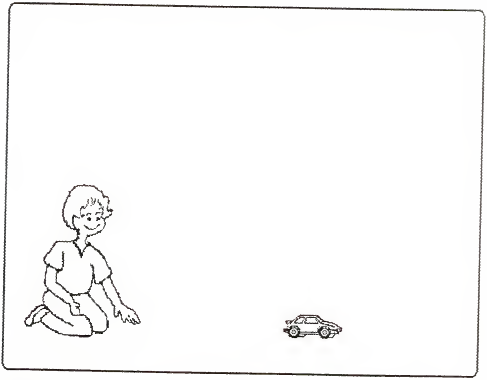

Figure 3-1. A Sample Frame in Outline Drawings (OD)

animation was constructed mainly on the basis of the verbal narration, so as to include only those critical aspects of the visual that were mentioned in the verbal description.

In the ODF version of computer animation, interior detail in figures (objects or people) was added to each frame of the OD version. If the critical information of a frame was a girl pushing a toy car, for example, the added interior detail would include the designs on the girl's clothing as well as shade and design patterns in the toy car (see Figure 3-2).

The ODFB version was presented with the same visual information as the ODF version except that appropriate

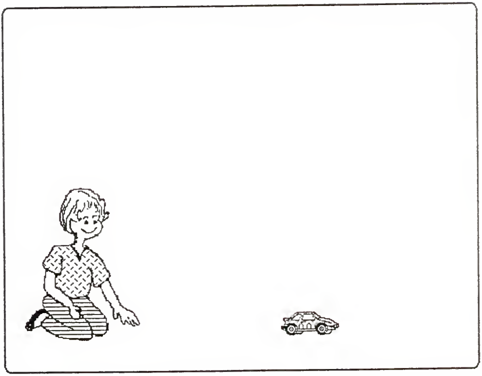

Figure 3-2. A Sample Frame in Outline Drawings with Added Figure Detail (ODF)

background information was provided in each frame. For example, the visual of a girl pushing a toy car in the ODF version would be embedded in a living room in the ODFB version (see Figure 3-3).

On the whole, each of the three versions of video treatments contained the same critical visual information. However, figure detail and background information were added to the ODF and ODFB versions, respectively.

In order to eliminate variables which may confound the research results, all pictures were developed as black-and-white representations. In this way, the possibility of color effect could be avoided.

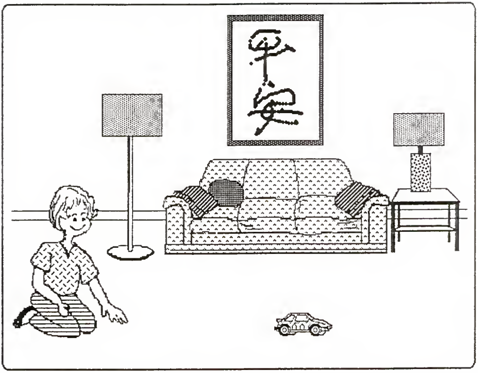

Figure 3-3. A Sample Frame in Outline Drawings with Added Figure Detail and Background Information (ODFB)

Instrumentation

A prototype of the pretest was developed and field-tested with a group of 52 fourth- and 55 eighth-grade students in a laboratory school in north central Florida in September, 1992. After the data were collected, an item analysis was conducted in order to select valid and reliable items of appropriate difficulty level. On the basis of the results of the item analysis, 12 inappropriate items in the prototype test were discarded. Kuder-Richardson 20 procedure was used to calculate reliability for the selected items ($r = .87$). Item difficulties ranged from relatively easy (85% correct) to relatively difficult (19% correct), and the average raw score was 15.44 with a standard deviation of 6.75.

The pretest measure dealt with the specific content covered in the selected video lesson (see Appendix A). It consisted of 28 multiple-choice questions which tested for students' comprehension of content which would be presented in the video lesson. The posttest was identical in style to the pretest and consisted of the same 28 items but arranged in a different order. The posttest was administered to the subjects two weeks after the pretest was given.

These measures required that the student had a thorough understanding of the concept of motion, gravity, and the law of inertia. They were designed to determine whether the students comprehended what was communicated and could use the information being received to explain some other phenomena. For example, the students were taught in the video lesson that a force is a push or a pull by seeing a girl pushing a toy car and a boy pulling it back. However, in the test the students were asked to apply what they learned to make a judgement in which of the different actions PUSH or PULL were used.

Procedure

The three video treatments were administered to 150 students in fourth and eighth grades. At both grade levels, each of the three classes was assigned at random to one of the video treatment groups-OD, ODF, and ODFB group. After being assigned the treatment groups, the subjects received the pretest to determine their prior knowledge level in the instructional content. However, since the possibility existed that the pretest might activate students' attention toward some specific areas of the video program when they would watch it later, the pretest was administered two weeks before the experimental treatments were delivered.

In order to prevent the teachers' expectancy from affecting the subjects' pretest scores, the teachers were asked not to provide the students with special help or hints during the pretest activity and they did not receive a copy of the pretest. The purpose of the teacher's presence in classrooms was to assist with the administration of the pretest. Before the pretest activity began, a 10-minute oral instruction was given by the experimenter to all subjects regarding the purpose of the study, the nature of the pretest, and the directions to answer questions. The estimated amount of time which the test would take was about 20-25 minutes.

During the 2-week period between the pretest and the experimental treatment, the teachers were requested not to teach any content areas relating to motion and force, gravity, and the law of inertia. In addition, they were also asked not to answer students questions concerning these areas.

After two weeks, subjects received their respective experimental treatments. Prior to the delivery of the treatments, the experimenter explained the procedures to the subjects. They were then asked if they had any questions about the procedures. Once it was determined that the subjects were comfortable in the experimental setting, the experimenter proceeded. The experimenter turned off the lights in the classroom and played the video treatment on a 20-inch monitor using a VCR. The approximate length of this video treatment was 14 minutes. Upon the completion of the video, the subjects received the posttest and were read the directions for answering the questions. At the end of the test, all subjects were thanked and proceeded with their regular classroom activities.

Data Analysis

Due to the limitations in the practical conduct of research in the public school settings, it was impossible to randomly assign individual students to treatments in this study. Instead, intact classes of students were used. Students' pretest scores were collected and analyzed as a means of determining the type of statistical technique used. If nonsignificant differences had occurred on the pretest scores among the treatment groups, then an analysis of variance (ANOVA) would have been used. Instead, because a significant difference was noted, an analysis of covariance procedure (ANCOVA) was conducted for main and interaction effects, while the pretest served as a covariate. In addition, a post hoc t-test was used to test for differences between pairs of means where significant differences among groups were obtained via the analysis of variance or covariance techniques.

CHAPTER 4
RESULTS AND DATA ANALYSIS

The purpose of this study was to examine the effects of visual complexity in motion visuals on cognitive learning of students in different grade levels. Three video lessons representing different levels of visual complexity in motion visuals were utilized to determined their effect on children's comprehension of the intended learning. To test the hypotheses stated in Chapter 1, a 3 × 2 factorial, pretest-posttest experimental design was used. Presented in this chapter are the results of the data analysis.

The Analysis of Covariance

Due to practical limitations associated with the random assignment of individual students, three intact fourth-grade and 3 eighth-grade classes were used as the treatment groups in this study. In order to determine whether there were existing group differences in achievement levels of subjects in different treatments, a pretest-posttest correlation and an ANOVA procedure were utilized. Pearson correlation coefficients indicated that the pretest was highly correlated to the posttest ($r = .75$, $p < .0001$). An analysis of variance also showed a significant difference, $F(2, 147)$

= 5.94, $p < .005$, for pretest scores among the three treatment groups. Therefore, an analysis of covariance procedure (ANCOVA) was used for analyzing main and interaction effects, while the pretest scores served as a covariate. Ferguson and Takane (1989) have suggested that a statistical (rather than an experimental) method may be used to control the effects of an uncontrolled variable and thereby permit a valid evaluation of the outcome of the experiment. The analysis of covariance is such a method. It is designed to reduce possible bias caused by differences between groups that exist before experimental treatments are administered.

Researchers have indicated that the validity of the analysis of covariance depends on how closely the data satisfy the necessary assumptions (Elashoff, 1969; Ferguson & Takane, 1989; Huitema, 1980). One of the assumptions is that the regression slopes across experimental groups are constant. If the slopes are heterogeneous, the treatment effects are not the same at different levels of the covariate. Consequently, the adjusted means can be misleading and the F tests can be biased (Huitema, 1980). Therefore, Ferguson and Takane (1989) and Huitema (1980) recommended that the assumption of the homogeneity of regression lines should be tested every time an analysis of covariance is performed.

It has been suggested that regression relationships among treatment groups would reflect an interaction between the independent variables and the covariate (Elashoff, 1969; Littell, Freund, & Spector, 1991; Saffer, 1985). Therefore, in this study individual interactions of each independent variables (treatment and grade) and pretest were calculated respectively. They were pretest and treatment, pretest and grade, as well as pretest, treatment and grade. The obtained F ratios for each interactions were the following: $F(2, 138) = 2.10$ ($p > .05$), $F(1, 138) = 2.81$ ($p > .05$), $F(2, 138) = 0.70$ ($p > .05$), which indicate no significant differences. This means that a constant regression relationship existed among experimental groups. The underlying assumption for the use of covariance analysis was not violated in this study.

Another important assumption necessary for the correct usage of a covariance analysis technique is that the covariate is independent of the treatment effect. Ferguson and Takane (1989) indicated that if treatments affect the covariate values, the calculation of adjusted treatment means may remove part of the treatment effect or produce a spurious treatment effect. In the present study, however, since the covariate (pretest) had been measured before the treatments were administered, there was no reason to suspect that the distribution of the covariate values was affected by the treatments. Thus, the assumption of independence of treatment and covariate was valid in this study.

In conclusion, since the data in the present study satisfied both crucial underlying assumptions for the use of covariance analysis, the statistical results were analyzed using an analysis of covariance procedure for main and interaction effects.

Results

The following null hypotheses are tested:

> Hypothesis 1: There is no significant differences in the mean achievement of subjects taught the same learning content using three versions of video programs that differ in the levels of visual complexity (ie, outline drawings, outline drawings with added figure detail, outline drawings with added figure detail and background information).

To test Hypothesis 1, an analysis of covariance with three between-group levels (outline drawings, outline drawings with added figure detail, and outline drawings with added figure detail and background information) was conducted. Overall descriptive statistics are presented in Table 4-1. In addition, the pretest means, posttest means, standard deviations, and adjusted means by the three treatments groups for different grade levels are reported in Table 4-2. As shown in Table 4-2, the trends of the adjusted mean scores for the three treatment groups in fourth and eighth grades were different. The fourth-grade subjects had the highest adjusted mean scores for the OD, followed by the ODF and the ODFB respectively, while the adjusted mean scores for the eighth graders were in the following order: the ODF highest, the OD next, and the ODFB lowest. However, the overall adjusted mean scores differed very little from group to group, a fact which was reflected in the small F ratio of the analysis of covariance procedure.

Table 4-1

Descriptive Statistics for Overall Adjusted Mean by Treatment Condition

Treatment	Overall Adjusted M
OD (N = 49)	19.83
ODF (N = 54)	19.65
ODFB (N = 47)	18.30

Table 4-2

Pretest Mean, Posttest Mean, Adjusted Mean by Treatment Condition for Grade 4 and Grade 8

Treatment	Pretest		Posttest		Adjusted
	M	SD	M	SD	M
4th Grade					
OD (N = 24)	12.79	5.46	18.04	7.38	17.90
ODF (N = 27)	14.67	4.10	18.67	5.58	16.81
ODFB (N = 27)	10.48	4.77	13.59	6.01	15.57
8th Grade					
OD (N = 25)	21.08	4.68	23.04	5.45	22.14
ODF (N = 27)	20.00	4.38	22.67	4.00	22.47
ODFB (N = 20)	17.55	7.04	19.90	6.31	21.30

Summary ANCOVA statistics are shown in Table 4-3. The analysis of covariance of treatment conditions demonstrates that there was no significant difference for the main effect of treatment, F(2, 143) = 1.64, $p > .05$. In addition, separate analyses of covariance were performed for each grade level (see Table 4-4). The obtained F ratios for the 4th-grade was F(2, 74) = 1.57, $p > .05$ and for the 8th-grade was F(2, 68) = 0.5, $p > .05$, both indicating a nonsignificant difference for the treatment effect. Therefore, this null hypothesis was not rejected.

Table 4-3

Analysis of Covariance of Treatment Condition and Grade Level

Source	DF	SS	MS	F	SIG
Treatment	2	61.59	30.79	1.64	NS
Grade	1	1.42	1.42	0.08	NS
Treatment × Grade	2	30.33	15.17	0.81	NS
Pretest (covariate)	1	2207.12	2207.12	117.72	S*
Error	143	2681.11	18.74		

*Significant at $p < .001$

Table 4-4

Analysis of Covariance of Treatment Condition for Grade 4 and Grade 8

Source	DF	SS	MS	F	SIG
4th Grade					
Treatment	2	66.54	33.27	1.57	NS
Pretest	1	1438.43	1438.43	68.01	S*
Error	74	1565.04	21.14		
8th Grade					
Treatment	2	15.53	7.76	0.50	NS
Pretest	1	833.05	833.05	53.86	S*
Error	68	1051.70	15.46		

*Significant at p< .001

Hypothesis 2: There is no significant difference in the mean achievement of subjects in different grade levels taught the same learning content using three versions of video programs that differ in the levels of visual complexity.

An analysis of covariance was also used in Hypothesis 2. The descriptive statistics by the grade levels for overall treatment effect and for individual treatment groups are presented in Table 4-5 and 4-6, respectively.

Table 4-5

Descriptive Statistics for Overall Adjusted Mean by Grade Level

Grade	Overall Adjusted M
4th Grade (N = 78)	19.83
8th Grade (N = 72)	19.14

Table 4-6

Pretest Mean, Posttest Mean, Adjusted Mean by Grade Level for OD, ODF, and ODFB

	Pretest		Posttest		Adjusted
	M	SD	M	SD	M
OD					
4th Grade	12.79	5.46	18.04	7.38	22.18
8th Grade	21.08	4.68	23.04	5.45	19.06
ODF					
4th Grade	14.67	4.10	18.67	57.58	20.74
8th Grade	20.00	4.38	22.67	4.00	20.60
ODFB					
4th Grade	10.48	4.77	13.59	6.01	15.43
8th Grade	17.55	7.04	19.90	6.31	17.41

As shown in Table 4-6, there was variance in fourth- and eighth-grade adjusted means for different treatment groups. However, the overall adjusted mean scores between these two groups differed narrowly. For Hypothesis 2, the analysis of covariance yielded an F ratio of F(1, 147) = 0.08 (see Table 4-3). Because this F ratio was not significant at the .05 level, the null hypothesis was not rejected.

> Hypothesis 3: There is no significant interaction between grade levels and three versions of video programs that differ in the levels of visual complexity.

As indicated by Table 4-3, the obtained F ratio for the interaction effect of levels of visual complexity and grade levels was F(2, 143) = 0.81. This F ratio was not significant at the .05 level and therefore, did not allow rejection of the null hypothesis.

Summary

The results of the data analysis indicated that providing different levels of visual complexity in motion visuals had no significant impact on children's comprehension of the intended learning. The variable of grade was not significant on subjects' ability to comprehend three versions of video programs that differ in the levels of visuals complexity. Also, no interaction between amount of visual complexity in motion visuals and grade level was found.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was to investigate whether the differences in the level of visual complexity in motion visuals have an effect on cognitive learning of students in different grade levels. Specifically, this study examined the relationship between two attributes of visual complexity (the amount of figure detail and background information) and children's comprehension of information presented in an animated instructional video.

A 3 (levels of visual complexity) × 2 (grade levels) factorial, pretest-posttest design was used to investigate the treatment effects. The instructional content selected was a 14-minute video lesson concerning the motion of objects in the universe. The lesson was divided into three units: (a) motion and force, (b) gravity, and (c) the law of inertia. Three videotapes, which were converted from three versions of black-and-white computer animation, represented three different levels of visual complexity in motion visuals for this study. They were outline drawings (OD), outline drawings with added figure detail (ODF), and outline drawings with added figure detail and background information (ODFB). There were 3 fourth-grade (N = 78) and 3 eighth-grade (N = 72) classrooms that participated in the study. These classrooms were randomly assigned to three different treatment groups. All subjects received a pretest to determine their prior knowledge level in the instructional content. After two weeks, subjects were given their respective experimental treatments and a posttest. The pretest and posttest consisted of 28 multiple-choice questions and were designed to test subjects' comprehension of the instructional content.

Findings

The following hypotheses stated in the operational null form were analyzed using an analysis of covariance procedure.

> Hypothesis 1: There is no significant difference in the achievement of subjects taught the same learning content using three versions of video programs that differ in the levels of visual complexity (ie, outline drawings, outline drawings with added figure detail, outline drawings with added figure detail and background information).
>
> The null hypothesis was not rejected.
>
> Hypothesis 2: There is no significant difference in the achievement of subjects in different grade

levels taught the same learning content using three versions of video programs that differ in the levels of visual complexity.

The null hypothesis was not rejected.

Hypothesis 3: There is no significant interaction between grade levels and three versions of video programs that differ in the levels of visual complexity.

The null hypothesis was not rejected.

Discussion

Level of Visual Complexity in Motion Visuals

The data analysis indicated that there was no significant treatment effect on student's comprehension of information presented in an instructional video. Subjects' comprehension levels were unaffected by the level of visual complexity employed in the design of their respective instructional treatments. Providing children with complex pictorial information, such as the addition of figure detail and background information, had no significant impact on their cognitive learning.

It has been suggested by realism advocates that learning would be more complete as the amount of visual information in the instructional materials increases (Carpenter, 1953;

Dale, 1946; Gibson, 1954; Morris, 1946). Some earlier studies have provided empirical evidence supporting this approach. They found that increased pictorial information in terms of figure detail and background information did result in higher level of picture recognition and recall (Antes & Metzger, 1980; Evertson & Wicker, 1974; Snowman & Cunningham, 1976). However, the results of the present study do not support realism theories and suggest that the use of complex visuals contributes little to facilitate children's comprehension of the instructional materials.

Additionally, this study does not support the Relevant Cue Hypotheses that too much irrelevant information in a visual display may impair the intended learning (Miller, 1957; Travers, 1964; Travers & Alvarado, 1970). This study does find that, however, the overall adjusted mean score for the most complex treatment group (ODFB) is the lowest one among the three treatment groups. Therefore, Dwyer's (1978) observation that learners do not need highly detailed visual stimuli for understanding the instructional materials is apparently supported by the present study.

There is a characteristic of this study that may have accounted for the lack of significant effect relating to visuals complexity. That is, in contrast to the prior research which was generally limited to addressing the effects of visual complexity on recognition and recall, the present study focuses on children's comprehension of visual information. Sigel (1978) has indicated that comprehension must be distinguished from recognition. To comprehend a picture is to extract meaning from the picture, whereas to recognize a visual refers to the identification or labeling of some parts in a picture and this learning task does not require understanding.

Over the past years, several researchers have tried to examine the differences in the cognitive processes between comprehension and recognition. For example, Bloom and others (1956) constructed a taxonomy of educational objectives in the cognitive domain. They classified the cognitive learning into 6 hierarchical classes: knowledge, comprehension, application, analysis, synthesis, and evaluation. The knowledge category has been defined as including "those behaviors and test situations which emphasize the remembering, either by recognition or recall, of ideas, material, or phenomena" (p. 62). The major behavior expected of a student in this category is to remember and recognize exactly the same stimuli encountered during the original learning situation. On the other hand, the comprehension category was defined by Bloom et al. as the ability to secure the total views of what the communication contained and to make use of them to new situations and problems. Therefore, Bloom and others concluded that the major distinction between the knowledge category and the comprehension one is that the essential psychological processes involved were different: the emphasis on knowledge (recognition or recall) involved little more than remembering, while the main focus on comprehension was drawing inferences.

With the increased attention to the field of cognitive psychology since the middle 1970s, research on learning has shifted from a behavioristic orientation to a concern with internal mental processes in learning (Shuell, 1986). Many educators and researchers have shown a growing interest in understanding more complex forms of learning such as comprehension. For example, Gagne (1985) investigated the various stages and phases involved in human information processing and found that "when the recall of what has been learned involves application to a new situation or to a novel problem, transfer of learning occurs" (p. 74). Although Gagne used the term "transfer of learning" to refer to the process that learners can bring knowledge or skills to a novel learning situation, according to Bloom's definition of comprehension described above, the process of transfer of learning is apparently similar to the process of comprehension. Gagne also indicated that learner's active construction and generalizing were two primary special internal processes involved in transfer of learning. However, a more precise investigation on these two processes is neither provided nor mentioned by the author.

Another theory on the process of comprehension was postulated by Bransford and Franks (1976). According to this theory, learning that involves comprehension should occur via a process of decontextualization. That is, in a learning situation knowledge is initially acquired in a specific context; in order for comprehension to occur, this knowledge must be transformed through a process of decontextualization so that it can be applied to a variety of different learning situations. Bransford and Franks suggested that decontextualization can be achieved through the process of shaping knowledge from concrete into abstract representations. However, the specific mechanism operating during the acts of decontextualizing and abstracting is still vague and not clearly defined in this theory. Most importantly, the major portion of this research is devoted to examining linguistic aspects of phenomena of comprehending. The role of visual information in affecting learner's comprehension of the communication is entirely overlooked. As a result, Shuell (1986) recommended that the phases that learners might go through in the more complex forms of learning are unknown at present, but "they undoubtedly exist and deserve our attention" (p. 429). New principles need to be generated for the desired learning outcome relating to the comprehension of relationships among many separate pieces of information.

Although considerable empirical research has focused on the relationship between pictorial complexity and student's cognitive learning, only a few studies have attempted to include comprehension as one of the learning tasks to be examined (e.g., Dwyer, 1967a, 1971a; Hozaki, 1988). Unlike other instructional tasks, however, various levels of visual complexity seldom make a significant impact on comprehension. For example, Dwyer (1971a) evaluated the relative effectiveness of different types of visual illustrations on different educational objectives and found that the different visual illustrations did make different effects on the drawing and identification tests. However, these visual illustrations failed to facilitate student achievement on the comprehension test. The oral presentation without visuals was found as effective as other visual presentations on student's comprehension. Dwyer indicated that the research results could be explained in the following manner: "the type of educational objectives measured by this test did not require students to utilize effectively the information presented in the illustrations" (p. 413). Unfortunately, the reason why comprehension does not require learners to utilize the visual information is not further clarified.

The results of another study by Hozaki (1988) provided a similar finding to Dwyer's (1971a). Hozaki investigated the effects of visual complexity on learner's physical performance and mental comprehension of paper folding. The results revealed that the realistic visuals yielded better physical performance than the simple line visuals and no visuals, but did not make a significant difference in student's mental comprehension.

Thus, according to the findings of prior studies and the present study, there is an indication that humans may employ different internal cognitive processes for recognizing than for comprehending a visual display. However, as Shuell (1986) has indicated, it is still not clear how these two mental processes are different. Are there different mechanisms involved? Does the visual information play dissimilar roles during the processes of remembering and comprehending? It is evident that more research has to be done before we can draw a general conclusion on these issues.

Grade Level

The results of this study indicated that there was no significant difference between fourth- and eighth-grade children's ability to comprehend visual information at various levels of visual complexity. Students in fourth- and eighth-grade performed equally well on their learning of visual information. The difference in the overall adjusted means between two grade levels was small. The overall adjusted mean scores were 19.83 for the fourth-grade children and 19.14 for the eighth grade level, respectively.

A number of researchers have theorized and tested the hypothesis that there is a developmental increase in ability to process visual information (Collins, 1970; Hagen, 1972; Hale & Taweel, 1974; Pick, Christy, & Frankel, 1972; Wadsworth, 1984). According to the research on the development of selective attention, older children have been found more capable of selectively attending to the relevant stimuli than younger children. Younger children tend to center perceptually on selected details of a picture without much concern for whether they are essential to the theme of the picture. Hagen (1972) who conducted a series of developmental studies, reported that children by seventh grade should be capable of focusing on certain parts of visual information while ignoring other parts.

In addition, several researchers have attempted to investigate the relationship between the complexity of a picture and a child's ability to process it (Evertson & Wicker, 1974; Hurt, 1988; Moore & Sasse, 1971; Pezdek & Chen, 1982). Unfortunately, due to the conflicting research results there is no clear indication that a definite developmental trend in processing visual information exists. The results of Gorman's study (1973) even indicated that there was no significant difference in performance in relation to the amount of pictorial detail and grade level. The present study supports Gorman's conclusion that the level of visual complexity in visual instruction has no effect on cognitive learning of students in different grade levels.

The lack of significant grade-level effect can probably be attributed to the fact that an insufficient difference in level of visual complexity existed among the versions of treatments. In reviewing prior studies in the field, it can be noted that most studies utilized a much wider range of variations in visual complexity for their treatments. For example, Moore and Sasse (1971) used photographs, paintings, and line drawings as the three levels of visual instruction. In Evertson and Wicker's study (1974) the three visual stimulus conditions presented to subjects also displayed significant variance: objects, photographs, and line drawings. In comparison, the three treatments used in the present research all were computer-generated line drawings. Although figure detail and background information were added to the two complex versions of treatments (ODF and ODFB), the variations among these treatments were far from the ones in the prior research.

Gorman (1973) has suggested a tolerance level hypothesis to explain the nonsignificant research results on the relationship between pictorial detail and grade level. That is, due to a tolerance level existing for some irrelevant information in a picture, the irrelevant detail may not interfere with learner's processing of the relevant information presented . Apparently, this research study is supportive of Gorman's assumption. In the present study, although the fourth- and eighth-graders differed narrowly in their overall adjusted means (19.83 vs. 19.14), there was much larger variance in their adjusted means for different treatment groups. For example, for the ODF treatment both fourth- and eighth-graders performed in similar ways (20.74 vs. 20.60); however, for the ODFB treatment fourth-graders experienced more difficulty than their eighth-grade counterparts (15.43 vs. 17.41). According to these data, it seems evident that the level of visual information contained in the most complex treatment (ODFB) is at the extreme end of fourth-graders' tolerance level. With the eighth-grade students this level of visual complexity does not appear to interfere as significantly with their learning.

On the other hand, the fourth-graders surpassed widely the eighth-graders in the adjusted mean scores for the OD treatment (22.18 vs. 19.06). The obtained F ratio was F(1, 46) = 4.01, which was very close to the level of significance (the critical value of F at the .05 level is 4.05). Therefore, it seems reasonable to assume that the amount of information in the OD treatment may be just adequate to engage the fourth-graders to learn, but does not contain enough complexity to facilitate the learning of eighth-grade students. In other words, the level of visual complexity contained in the simplest treatment (OD) is appropriate to the fourth-grader's tolerance level. However, it is so simple that eighth-graders become disinterested and do not achieve the intended learning.

In summary, on the basis of the preceding analysis, if this study had utilized a wider range of visual complexity among the treatments (e.g., the inclusion of a realistic video version or a more simpler outline drawing version) significant achievement differences in different grade levels may have occurred. However, there is still very little experimental evidence available as to what the limit of the tolerance level is. Does the tolerance level associate with age level? More research should be conducted to explore these questions.

Implications

There are several important implications for educational researchers and instructional designers to consider from the results of this study. First, according to the subjects' progress in their achievement scores, it is apparent that the use of visual instruction does improve student's cognitive learning. However, the three levels of visual complexity in motion visuals employed in this research study do not have any differential impact on children's comprehension of the instructional materials. The more complex visuals are no more effective than the simple one. Added figure detail and background information neither facilitate nor impair student processing visual information. Therefore, it appears that the issue of whether to add extra pictorial information in instructional materials should be an economic rather than an instructional consideration. As Dwyer (1972) has stated, "...if two or more types of visuals are equally effective in increasing student achievement, then in terms of time, talents, and funds the least expensive type should be used" (p. 14). Indeed, although remarkable technological advances have made complex visuals available, it is irrational to produce expensive visual materials when less costly materials have proved to be equally effective. Instructional designers and educators should consider their fiscal budget limitations before making a final decision in selecting and producing appropriate visuals for learners.

Second, the results of this study offer evidence that there is no significant relationship between the treatments and grade levels on learner's comprehension. No one treatment condition serves to provide students in different grade levels with a more efficacious visual design strategy for affecting their achievement. Therefore, visual complexity may not be an important factor to be considered when teachers and instructional designers determine how to present motion visuals in order to facilitate the comprehension of learners at different ages. Either a common simple outline drawing or detailed drawing with background format can be used with equal effectiveness with a range of students from grade 4 through grade 8. However, since Gorman's (1973) tolerance level hypothesis seems an unresolved issue in this research, this study does suggest that teachers and instructional designers should take visual complexity into account when the intended learners are beyond the range of grade levels from fourth to eighth.

Another implication of this study is that since level of visual complexity is not a physical attribute restricted within a specific medium, the findings of this study may broadly apply to learning from film, television, computer, interactive video, or multimedia systems. That is, extra pictorial information cannot facilitate comprehension of the information presented in any of the various motion visuals. Even though advanced media such as videodisc or digital video interactive (DVI) can present information that is more realistic, the incorporation of complex and detailed visuals into instructional materials apparently is not necessary.

Recommendations

The results of this empirical study support the need for more extensive investigation concerning the design of visual instruction. The following recommendations are made for additional study in this area:

1. The present study examined the effect of visual complexity on comprehension only. Different cognitive learning tasks could be employed to determine if the factor of visual complexity only influences specific cognitive learning tasks.
2. The visual treatments in this study all were computer-generated line drawings. A wider range of variations in visual information among treatments could be used to determine if the level of complexity in motion visuals affects children's learning.
3. The subjects selected for this study were fourth-grade and eighth-grade children. Additional research could use subjects at a greater age difference to determine whether the effects of visual complexity in motion visuals interact with learner age.
4. Physical science was the subject matter selected in this study. A continued study could be designed to utilize different subject content areas to determine if the effect of visual complexity is restricted to the specific subject matters.
5. The visual treatments in this study were developed as black-and-white representations. Future research could add color and other cueing strategies to the motion

visuals as variables to investigate if children's comprehension is affected by them.

6. A multiple-choice test was developed as the instrument for this study. The same study could be replicated with other types of measures to examine whether different results from the present study would be found.
7. Since only a multiple-choice test was employed in the study to measure subject's comprehension, additional research could be conducted to compare the effectiveness of multiple-choice tests relative to other types of instruments on evaluating learner's comprehension level.
8. Since a statistical method (ANCOVA) was used in the present study to control subject's existing differences, the same research could be replicated by randomly assigning individual subjects to treatments in an attempt to determine whether the classroom effect influences the results of this study.

Summary

Pictures are a versatile instructional tool. They can help children learn many different tasks, such as learning from oral prose (Levin & Lesgold, 1978), learning from nonfictional passages taken from newspaper (Levin & Berry, 1980), learning from written text (Levie & Lentz, 1982), and word recognition (Willows, 1978). However, studies of visual instruction also show that the inclusion of a picture in instruction does not automatically improve student achievement (Dwyer, 1978; Levie & Lentz, 1982; Peeck, 1987). Different visuals containing different amount of visual complexity may affect learning differently.

Visual complexity can vary among a great number of different attributes. The amount of interior detail in figures and presence of background information are two attributes which have been identified by researchers as important factors influencing learner's processing of visual information (Dwyer, 1978; Fleming, 1987; Franken, 1977; Nelson, Metzler, & Reed, 1974; Travers, 1969).

In a visual display, critical figures may show extreme variations in amount of interior detail. In some studies, researchers have directly manipulated the amount of figure detail in pictures to determine whether extra interior detail facilitates different levels of learning in the cognitive domain (Cody & Madigan, 1982; Dwyer, 1978; Evertson & Wicker, 1974; Jesky & Berry, 1991; Nelson, Metzler, & Reed, 1974; Ritchey, 1982; Travers, 1969). Unfortunately, conflicting results are found among these studies.

In general, background information refers to the surrounding information in which the critical figure is embedded (Borg & Schuller, 1979; Fleming & Levie, 1978;

Sparks, 1973). According to this definition, pictures may vary in the extent to which the critical figure in the picture is presented in context or in isolation. A number of empirical investigations have focused on the influence of the presence or absence of background information in a visual (Antes & Metzger, 1980; Borg & Schuller, 1979; Franken, 1977; Spaulding, 1956; Whitaker & Sullivan, 1980). However, the research results thus far are inconclusive and contradictory.

On the other hand, many researchers find that the effect of visual complexity interacts with learner age. Many empirical studies have been conducted which attempt to establish the relationship between the complexity of a picture and a child's ability to process it (e.g., Collins, 1970; Evertson & Wicker, 1974; Hagen, 1972; Hale & Taweel, 1974; Moore & Sasse, 1971; Pezdek & Chen, 1982; Pezdek, 1987). Although research results appear inconsistent to some extent, in general researchers agree that there are differences in how the children of various age allocate their attention to a visual task. Unfortunately, at present there is very little guidance for educators in selecting visuals that are appropriate for use with specific groups of learners.

An examination of prior studies concerning the effect of visual complexity on learning determined that there are two limitations found among them. First, few research efforts have been devoted to an examination of the effects of visual complexity on children's cognitive learning at higher levels. Secondly, most of these studies have used static rather than motion visual stimuli as the material to be learned. Therefore, in view of the increasing requirement of higher-level learning and use of motion visuals in school settings today, it appears that more research needs to be conducted regarding these area.

The purpose of this study was to examine whether, or to what extent, differences in the level of visual complexity in motion visuals have an effect on student's comprehension at different grade levels. Specifically, the amount of figure detail and background information were two attributes of visual complexity examined. The results of this study indicated that providing different levels of visual complexity in motion visuals had no significant impact on children's comprehension of the intended learning. The use of complex visuals contributed little to facilitate learner achievement. Also, no interaction between amount of visual complexity in motion visuals and grade level was found. These results imply that the comprehension level of children in grade 4 through grade 8 may not be affected by visual complexity in motion visuals. The issue of whether to add extra pictorial information in instructional materials should be an economic rather than an instructional consideration. Instructional designers and teachers are encouraged to consider fiscal limitations before selecting and developing visual materials.

APPENDIX A
PRETEST

Directions: In the following multiple-choice questions, select the answer which you feel best answers the question or completes the statement, and blacken the corresponding space on the answer sheet. Mark only one answer to each question.

1. A force is a push or a pull. In which of the following actions is PUSH used?
   A. Opening a drawer.
   B. Tacking down a memo on a board.
   C. Opening a can of soft drink.
   D. Peeling off a self-adhesive label.

2. When you stand in front of your home, the place where you are is your
   A. place.
   B. position.
   C. location.
   D. site.

3. A force is a push or a pull. In which of the following actions is PULL used?
   A. Erasing the chalkboard.
   B. Pressing a TV power switch on/off.
   C. Hitting a baseball with a bat.
   D. Opening a sealed sandwich bag.

4. Motion is a change of location. In what game is motion NOT important?
   A. Basketball
   B. Football
   C. Solving a riddle
   D. Dancing

5. Which of the following can cause objects to move?
   A. Pull
   B. Kick

C. Push
D. All of the above

6. When you ride a bike, the less force you use will cause you to go:
   A. faster.
   B. slower.
   C. the same.
   D. None of the above.

7. In a tug-of-war, if each person has equal strength, team A has 10 people, team B has 12 people, which team will win?
   A. Team A
   B. Team B
   C. Neither team will win.
   D. We do not know.

8. Imagine you are in a world with no gravity. Do you know what will happen?
   A. You will float in the air like an astronaut.
   B. Your weight will be zero.
   C. You cannot play on a seesaw.
   D. All of the above

9. In the following statements about Isaac Newton, which one is FALSE?
   A. He studied animals.
   B. One of his findings has been used for designing seat belts.
   C. His first law of motion is also called the law of inertia.
   D. He is a great English scientist.

10. The force used to lift a bag of 10 pounds is stronger than the force used to lift a bag of
    A. 9 pounds.
    B. 11 pounds.
    C. 20 pounds.
    D. 30 pounds.

11. According to your knowledge about weight, Mary weighs 95 pounds. This means that

A. she is skinny.
B. she needs to exercise more.
C. gravity is pulling her down with a force of 95 pounds.
D. none of the above.

12. In which of the following actions is the force of PUSH NOT used?
A. Typewriting an article.
B. Playing a piano.
C. Removing a nail from the wall.
D. A and B.
E. B and C.

13. The resistance of objects to any change in motion is called
A. gravity.
B. inertia.
C. location.
D. pull.

14. Suppose a crowded bus stops suddenly. The people standing in the aisle seem to be
A. thrown forward.
B. thrown backward.
C. not moving.
D. It cannot be decided.

15. In a normal situation, is it easier to push an 8-pound box or a 4-pound box?
A. The 4-pound one.
B. The 8-pound one.
C. It is the same.
D. It cannot be compared.

16. Why can a seat belt protect you from bumping into or even going through the windshield?
A. Because automobile safety engineers design it.
B. Because the seat belt is elastic.
C. Because the seat belt is fastened around you and is attached to the car's frame.
D. None of the above.

17. Gravity:
    - A. is the pull of the earth.
    - B. is a very important force in our world.
    - C. can hold everything down no matter of any situation.
    - D. A and B only.
    - E. B and C only.

18. Why doesn't the water fall on John when he fast swings a pail of water upside down over his head? Because
    - A. the water's inertia tends to keep it moving in a straight line.
    - B. it is a magic trick.
    - C. the gravity of Earth disappears momentarily.
    - D. John is a magician.

19. Which one of the following statements is FALSE?
    - A. Forces can be strong or weak.
    - B. Forces can change the speed of moving things.
    - C. Things can move without a force.
    - D. According to Newton's First Law of Motion, a ball will not move unless somebody kicks or pushes it.

20. Which one of the following statements is TRUE?
    - A. You can see gravity and see what it does.
    - B. The pull of gravity is the same on everything.
    - C. Newton's First Law of Motion is also called the law of gravity.
    - D. Jack moves off of the branch and drops to the ground. This is an example of gravity.

21. In which of the following actions is the force of PULL used?
    - A. Pedaling a bicycle.
    - B. Throwing the javelin.
    - C. Kicking a ball.
    - D. Raising the blinds.

22. The pull of gravity:
    - A. is different on different things.
    - B. acts on everything in the earth.
    - C. does not act on a pail of water being swung around very fast.
    - D. A and B only.

E. B and C only.

23. Isaac Newton:
    A. is a great English scientist.
    B. studied motion.
    C. found the law of inertia.
    D. All of the above.

24. Suppose a crowded bus starts up suddenly. The people standing in the aisle seem to be
    A. thrown forward.
    B. thrown backward.
    C. not moving.
    D. none of the above.

25. In the following statements about gravity, which one is FALSE?
    A. Gravity makes the dishes stay on the table.
    B. Sometimes gravity cannot overcome object's inertia.
    C. Your weight is a measure of the pull of gravity.
    D. Gravity does not act on a ball being thrown up into the air.

26. Forces:
    A. can start an object moving.
    B. sometimes act together, and sometimes act against each other.
    C. can be strong or weak.
    D. All of the above.

27. After you hit a ball, the tendency of the ball to continue moving in the same direction is called
    A. gravity.
    B. magic.
    C. force.
    D. inertia.

28. Which one of the following statements is FALSE?
    A. The harder a cheerleader throws a baton up into the sky, the less chance it will come down.
    B. Everything on the earth is being pulled by gravity.
    C. Forces make things move.
    D. Forces can change the speed of moving things.

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BIOGRAPHICAL SKETCH

Lin Ching Chen was born in 1962, in Taiwan. She received her Bachelor of Arts degree in history from the National Taiwan University in 1984. After working in Academic Sinica in Taiwan for a year, she moved to the United States in 1985 and attended the University of Arizona at Tucson, Arizona. She received her Master of Education degree in educational media in 1987.

After graduation from UA, Ms. Chen moved to Gainesville, Florida, and was employed as a photographer in the Department of Anatomy and Cell Biology at the University of Florida. In 1988, she continued her doctoral study in the Department of Instruction and Curriculum.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Education.

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